REPRODUCTION AND RECRUITMENT IN THE DOUGHBOY SCALLOP, *CHLAMYS ASPERRIMUS*, IN THE D'ENTRECASTEAUX CHANNEL, TASMANIA

WILL ZACHARIN

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Doughboy scallops in the D'Entrecasteaux Channel can grow to a shell height of 110mm. Reproductive output in this population displays both temporal and spatial changes. The highest gonosomatic index recorded was 45% for a doughboy of 105mm. The number of mature eggs released in the 90–95mm size class was significantly different between two annual peak spawnings and there is evidence for secondary or partial spawnings. Recruitment monitoring through the deployment of spat collectors and sampling of the populations suggests that hydrodynamic influences play an important role in recruitment success.

Will Zacharin, Sea Fisheries Division, Department of Primary Industry and Fisheries, GPO Box 619F, Hobart 7001, Tasmania; 20 June 1994.

The doughboy scallop, *Chlamys (Mimachlamys) asperrimus* (Lamarck,1819), is an abundant benthic bivalve found throughout southern Australia. Large populations extend over wide areas in Bass Strait, and a commercial and recreational dredge fishery for the species has operated irregularly in the D'Entrecasteaux Channel in southeastern Tasmania since the 1930's (Perrin & Croome,1988). An annual recreational dive fishery in the D'Entrecasteaux Channel is now the only remaining fishery.

For such a prominent member of the southern Australian benthic community, surprisingly little information exists in the scientific literature on the life history of the species. Larval and juvenile development of the doughboy were studied by Rose & Dix (1984); observations on epizoic sponge associations with the doughboy have been reported by Pitcher(1981) and Pitcher & Butler (1987), and some factors affecting mortality were described by Chernoff (1987). However, no studies have been conducted on growth, reproduction or population dynamics.

This study describes the reproduction and recruitment of the doughboy scallop in the D'-Entrecasteaux Channel, a semi-enclosed inshore waterway in southern Tasmania (Fig.1).

MATERIALS AND METHODS

A sample of 10–50 doughboys was collected from the same population in Simpson's Bay at 14 day intervals over 28 months (1 July 1988–27 November 1990). In the laboratory the animals were measured (shell height to the nearest 0.1mm) and total somatic and gonad tissue were weighted to the nearest 0.1g. Sex was determined according to colour of the gonad, males being white and females orange. Gonosomatic Index (GSI) was calculated as a ratio of gonad weight to somatic tissue weight. A significant decrease in the index was considered to be an indication of spawning (Dredge,1981; Sause et al.,1987; West, 1990). The terminology of stages in the gonad reproductive cycle was based on that of *Pecten fumatus* (Sause et al.,1987), *Chlamys varia* (Shafee & Lucas,1980) and *Amusium balloti* (Dredge,1981).

A fecundity index was developed using an indirect method, in which the difference in gonad weight of mature female scallops immediately prior to spawning and after spawning was calculated. This weight loss on spawning can be used as an index of the number of ova released from the gonad. The underlying assumptions are that mature ova prior to spawning have the same mass from year to year, and ova mass is the same across all size classes.

Regular surveys of doughboy populations in the D'Entrecasteaux Channel have been conducted by the author since 1985 to monitor recruitment. Between 1985 and 1988, 110–119 random stations within each statistical area were sampled using a 2.5m wide toothed scallop dredge (Zacharin, 1986,1987,1988). Since 1989, scallop surveys have been conducted by diving, to more accurately sample doughboys in the size range 30–40mm (1+ animals) (Zacharin,1991a,b; Zacharin et al.,1990).

As scallops are usually distributed at low densities over large areas and at high densities forming 'commercial beds' over small areas, sampling

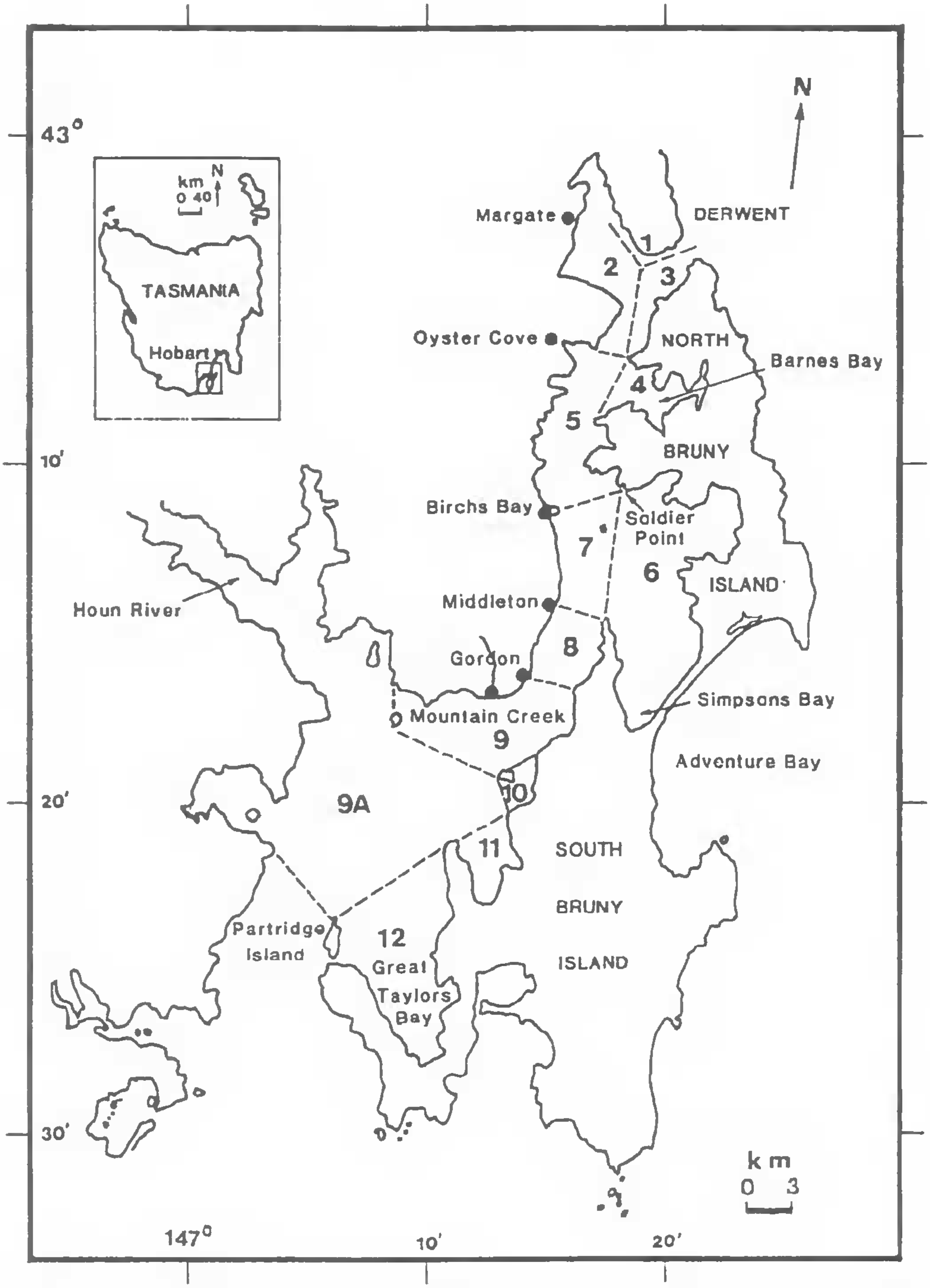

FIG.1. D'Entrecasteaux Channel as divided into statistical areas by Fairbridge (1953) for conducting scallop surveys. The same boundaries were used for the dredge and dive surveys between 1986 and 1992. (from Perrin & Croome,1988)

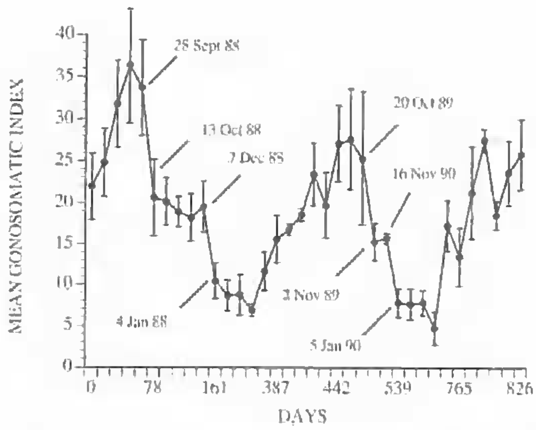

FIG.2. Seasonal changes in mean gonosomatic index in the female doughboy scallop from the D'-Entrecasteaux Channel. (Error bars =one standard deviation.).

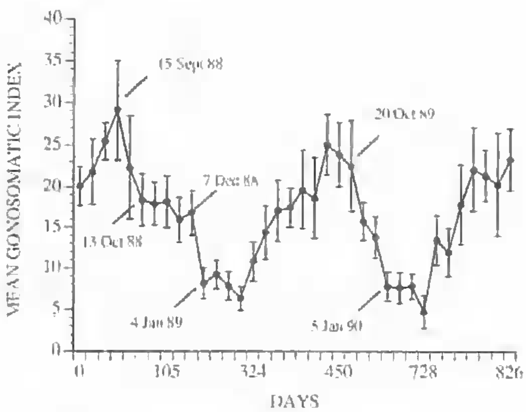

FIG.3. Seasonal changes in mean gonosomatic index in the male doughboy scallop from D'Entrecasteaux Channel. (Error bars=one standard deviation.)

technique must compensate for this fact. To adjust for this pattern of distribution, diver surveys were conducted using the following procedure. A number of random sampling points were distributed over an area to give an indication of scallop distribution. Further non-random sampling points were chosen based on previous catch history of the area and from reported sightings by divers. At each site a 100m transect line weighted with lead and buoyed at each end was deployed parallel to the current. Two divers swam along the transect collecting all scallops within 1m of the weighted line. It is important to deploy the line with the current and to swim with the current, as any scallops disturbed by the deployment of the line may move. As scallops tend to swim off the bottom and then free-fall to the substrate the majority are more likely to remain in the transect area if deployment is parallel to the current. The data were assembled as both total size frequencies for the whole of the channel area and as size frequencies of scallops in the various statistical areas.

Spat collection was conducted using small orange coloured onion bags with dark monofilament mesh filling as a settlement substrate. The

TABLE 1. Description of gonads and the histological condition of the various stages in the annual reproductive cycle of the scallop, *Chlamys asperrimus* from the D'Entrecasteaux Channel, Tasmania.

Stage	Female	Male
(1) Resting	Gonad small, flat and yellow brown. Composed of loose connective tissue. Intestinal loop visible. Ciliated ducts present	
(2) Early development	Slight increase in gonad size. Follicles with primary oogonia or spermatogonia. Clear differentiation of male and female gonads. Intestinal loop not visible.	
(3) Late development	Gonad increased in volume, tip being tapered.	
	Gonad orange.	Gonad white.
(4) Mature	Gonad volume large with rounded tip. Little connective tissue.	
	Follicle packed with mature irregular polygonal oocytes.	Large number of spermatozoa. Follicles tightly packed.
(5) Spawning	Free space in the centre of the follicles as gametes are expelled. Appearance of more connective tissue. Loss of gonad colour.	
(6) Spent	Follicles nearly empty of all gametes. Increase in connective tissue. Phagocytes predominate.	

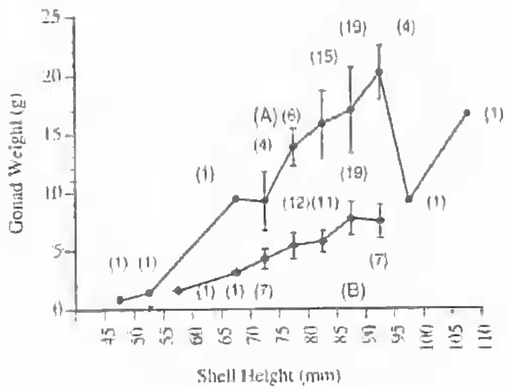

FIG.4. Fecundity index shown as a relationship between shell height (5mm intervals) and gonad weight for mature samples (A) collected on 15 and 28 September 1988 and immediate post-spawning samples (B) on 13 and 20 October 1988. Number of scallops shown in brackets.

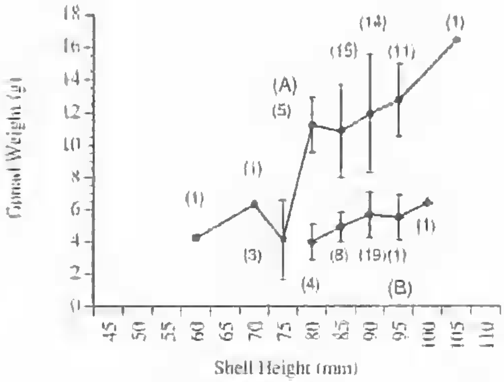

FIG.5. Fecundity index shown as a relationship between shell height (5mm intervals) and gonad weight from mature samples (A) collected on 4 and 12 October 1989 and immediate post-spawning samples (B) on 2 16 November 1989. Number of scallops shown in brackets.

first spat collectors were deployed on 18 September 1988 at various locations throughout the channel area. Sites were selected where tidal flow was greater around prominent headlands and islands. Collectors were observed each month to assess the intensity of spat settlement.

RESULTS

Reproduction

Six distinct stages of development were recognised (Table 1). During late summer to autumn (January–March) gonads were completely spent and appeared to be in a 'resting phase'. Accurate macroscopic identification of sex for the majority of individuals during the 'resting phase' proved to be impossible.

Fortnightly changes in mean GSI of females and males (Figs 2,3) are interpreted as increases in gonad weight due to follicular development and production of gametes; rapid decrease in gonad weight in September–October was indicative of spawning. The differences in gonad weights (being an index of ova number) for grouped samples (5mm) indicated a significant increase in ova number for the older and larger scallops (Figs 4,5). With the exception of rare large doughboys, gonad weight increased with size and peaked in the 90–95mm size class. Male GSI peaked earlier than female, and males appeared to commence releasing sperm earlier than females shed ova (Figs 2,3). GSI peaked earlier in 1988 (September) than in 1989 (October). The index of fecundity was significantly higher in 1988 with the average gonad weight of the 90–95mm size class being 38% higher than in 1989 (t-test, $P<0.02$). Gonad weight loss on spawning in 1988 for this size class was 63.12% of total gonad weight compared to 56.83% in 1989 (Figs 4,5). A significant decrease in gonad weight (suggestive of spawning) was observed between September and December in each year.

In both years there was a second rapid decline in gonad weight in late December–early January. This has been interpreted as being indicative of partial spawning. Data obtained from spat collectors supports this concept. It is not known what percentage of gametes released through earlier partial spawnings or late spawnings are competent; or their contribution to recruitment. However, collectors placed at a number of locations in

TABLE 2. Results from spat collectors deployed adjacent to Huon Island in the D'Entrecasteaux Channel (statistical area 9) during 1988/89.

Date	Number/ Collector	Mean (mm)	Standard deviation
9/12/88	158-208	4.26	1.59
25/1/89	316	5.75	0.99
28/2/89	230	10.43	1.97
21/3/89	226-306	12.65	2.69
30/4/89	130-176	16.43	4.29

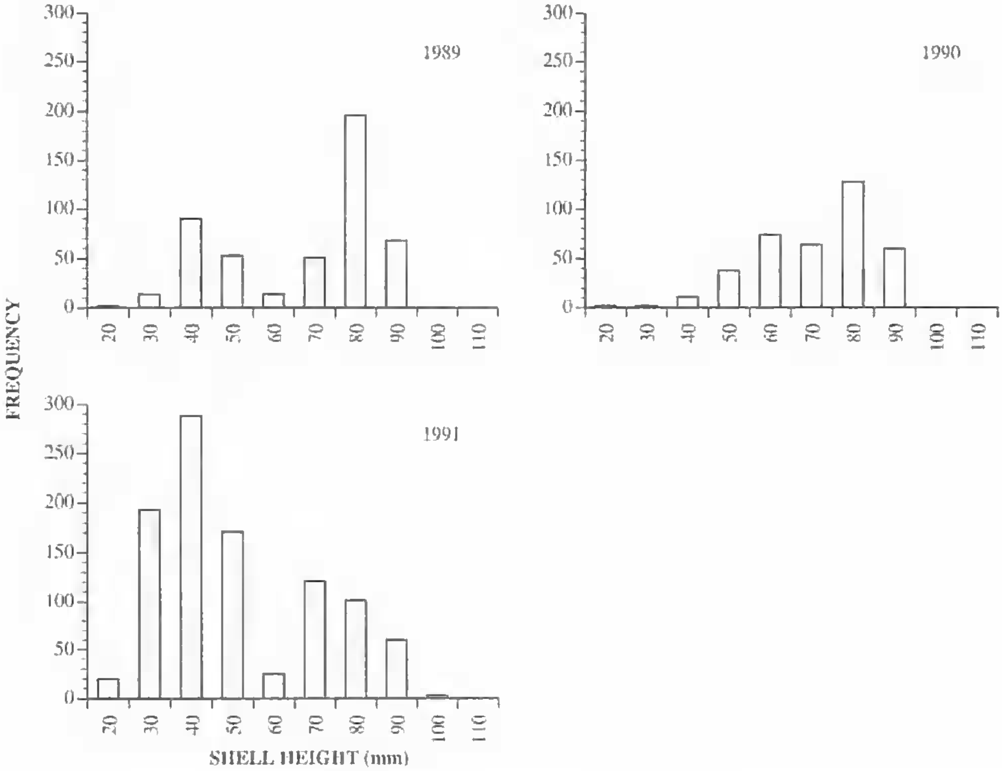

FIG.6. Frequency histograms of all doughboy scallops measured from all sites sampled during the 1989, 1990 and 1991 dive surveys.

the D'Entrecasteaux Channel between September and April suggest that minor settlement occurs over a number of months, but there is one major event (Table 2). The highest spat numbers (<5mm), in December, suggest the major September/October spawning contributes to greater spat settlement.

Sex ratio for all samples collected was 1:1. There was no change in sex ratio observed between different ages or shell height.

Recruitment

Fig.6 shows the change in size frequency from 1989 to 1991. As the diver surveys were conducted between March and April each year, an index of potential recruitment was represented by numbers of the 1+ year class (30–40mm size range). Both survey results (Zacharin 1989, 1991, Zacharin *et al.* 1990) and observations of spat settlement indicate that there was strong settlement in 1988 and 1990. Size frequency histograms (Fig.7) demonstrate the spatial patchiness of scallop settlement and subsequent recruitment by the relative abundance of 30–40mm scallops. In statistical areas 7, 8 and 9 such scallops were relatively abundant, particularly in 1991. In areas 6 and 10, 30–40mm scallops were rare except in the 1991 samples, whereas area 11 supported few recruits throughout the entire study period. The remaining seven statistical areas (Fig.1) were not sampled with sufficient regularity to give meaningful data.

DISCUSSION

Sustainable management of a scallop fishery is dependent in part on an understanding of the reproductive cycle and environmental influences that may change or alter the timing and frequency of spawning. An important objective of the fishery manager is to identify the minimum size and age at first maturity, to reduce the potential for recruitment overfishing. Knowledge of the reproductive cycle is also important in determining when, and to a lesser extent, where recruitment to the fishery may occur (Orensanz,1986).

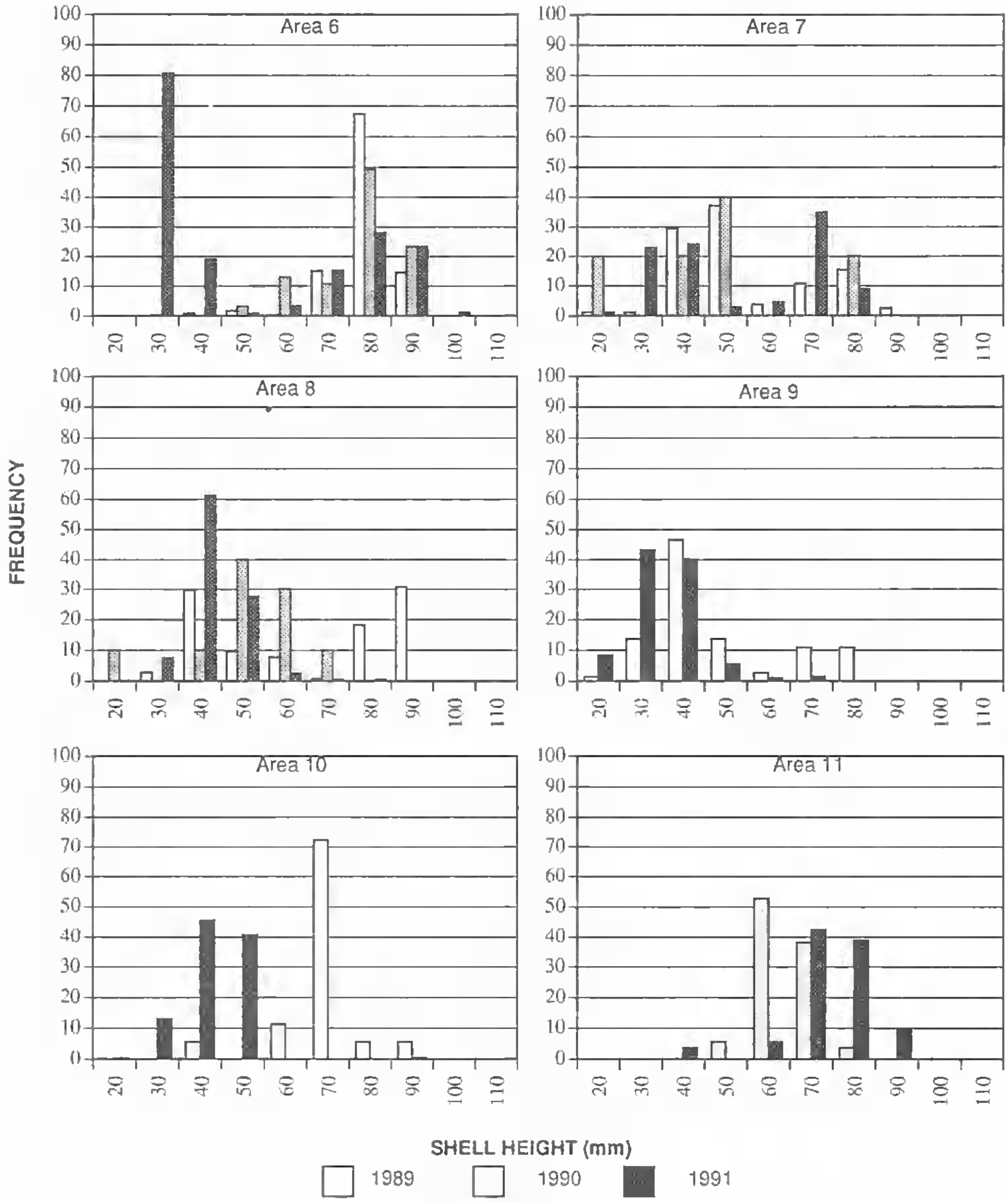

FIG. 7. Size frequency histograms by statistical area for doughboy scallop populations from dive surveys conducted in 1989, 1990 and 1991. Areas 10 and 11 have data from 1990 and 1991 only, while Area 9 has data from 1989 and 1991 only.

C. asperrimus is a synchronous spawner, as is *P. fumatus* (Sause et al., 1987) and *E. bifrons* (Dix & Sjardin, 1975). However males matured and released sperm earlier than females. Gonads began early development in late March–early April. Maturation continued through the winter months and a major spawning event occurred in late September–mid-October. A minor spawning event was observed in December; however, the significant decrease in GSI at this time may have been a consequence of oocyte lysis and reabsorption (Zacharin pers. obs.). Rose & Dix (1984) collected zygotes from individuals in the D'-Entrecasteaux Channel during September/October in their study of the larvae of *C. asperrimus*, which is consistent with the results of this study.

Fecundity generally increased with shell height and age and peaked in the 90–95mm size class. Few doughboys larger than 95mm were found. Of the two located, one 101mm individual found in 1989 had the highest gonad weight recorded (16.4g).

The results illustrate the need to monitor populations over a number of seasons to establish the timing, frequency and level of ova release during spawning. The major spawning in 1988 occurred between 15 September and 20 October with the maximum mean GSI being 37.72% on 15 September. In 1989 the major spawning occurred four weeks later between 4 October and 16 November on the basis of GSI changes. Maximum gonad index is reached 2–3 weeks prior to spawning and some gamete 'leakage' occurs prior to the main spawning event. This was revealed by early spat settlement in the collectors.

Gonad weight loss was used as a measure of fecundity, as the number of ova released in any year may widely fluctuate. A count of total ova number, as is performed in many fecundity studies, may not have highlighted this difference. Total ova number released annually is preferable to the number of mature ova contained in the ovary. Research into stock/recruit relationships may be easier to interpret if the former and not the latter measure is more widely used.

Spat collection was an important process used to validate identification of both the peak spawning period and secondary or minor spawning events. During the two year period 1988/89–1989/90, highest spat numbers were recorded in December, with shell height frequency histograms indicating a further minor settlement in February. Spat <2mm shell height were observed in spat collectors during November–March, indicating some partial spawning or 'leakage' of gametes at a low level over a 5 month period. This gamete leakage has been reported for a number of other scallop species (Brand et al.,1980; Ciocco,1991; Hortle & Cropp,1987; Sause et al.,1987; Wolff,1988).

Recruitment in the D'Entrecasteaux Channel region has been spatially and temporally erratic. Settlement of juveniles was high in both 1988 and 1990 with the highest number of recruits observed in 1990. Models of larval advection show that the strength and direction of wind at the time of spawning is an important determining factor in the distribution of scallop larvae. (Butman,1987; Orensanz et al.,1991; Young et al.,1992). This is well illustrated by the spatial changes in spat settlement and distribution of juvenile scallops in the D'Entrecasteaux Channel.

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